

WHAT IS CLAIMED IS:

1 1. A Schottky diode comprising:
2 a metal layer and a semiconductor region forming a Schottky barrier
3 therebetween;
4 a plurality of charge control electrodes formed in the semiconductor region so
5 as to influence an electric field in the semiconductor region, wherein at least two of the
6 plurality of charge control electrodes are electrically decoupled from one another so as to be
7 biased differently from one another; and
8 a dielectric material insulating each of the plurality of charge control
9 electrodes from one another and from the semiconductor region.

1 2. The Schottky diode of claim 1 further comprising an anode electrode
2 coupled to the metal layer and a cathode electrode coupled to the semiconductor region, the
3 plurality of charge control electrodes being located between the anode and cathode
4 electrodes.

1 3. The Schottky diode of claim 1 wherein the semiconductor region
2 comprises a substrate and an epitaxial layer extending over the substrate, the plurality of
3 charge control electrodes being formed in the epitaxial layer.

1 4. The Schottky diode of claim 1 wherein the plurality of charge control
2 electrodes is in a plurality of trenches formed in the semiconductor region.

3 5. The Schottky diode of claim 4 wherein the plurality of charge control
4 electrodes in the plurality of trenches are insulated from one another and from the
5 semiconductor region.

1 6. The Schottky diode of claim 4 further comprising a plurality of
2 shallow regions each formed in a top surface region of the semiconductor region between
3 adjacent pairs of the plurality of trenches such that the metal layer is in direct contact with the
4 shallow region, the shallow region having the same conductivity type as but a lower doping
5 concentration than the semiconductor region.

1 7. The Schottky diode of claim 6 wherein the semiconductor region and
2 the shallow region are n-type.

1 8. The Schottky diode of claim 1 further comprising a biasing element
2 coupled to bias the at least two of the plurality of charge control electrodes differently from
3 one another.

1 9. The Schottky diode of claim 1 wherein each of the plurality of charge
2 control electrodes comprises polysilicon.

1 10. The Schottky diode of claim 1 wherein the plurality of charge control
2 electrodes is biased to produce a substantially uniform electric field in the semiconductor
3 region.

1 11. A method for forming a Schottky diode having a semiconductor
2 region, the method comprising:
3 forming a plurality of charge control electrodes in the semiconductor region so
4 as to influence an electric field in the semiconductor region, wherein at least two of the
5 charge control electrodes are adapted to be biased differently from one another; and
6 overlaying the semiconductor region with a metal layer to thereby form a
7 Schottky barrier therebetween.

1 12. The method of claim 11 further comprising forming a plurality of
2 trenches in the semiconductor region, and wherein the step of forming a plurality of charge
3 control electrodes comprises:
4 lining each of the plurality of trenches with an insulating layer;
5 depositing a first conductive material in each trench and then etching the first
6 deposited conductive material to form a first charge control electrodes in each trench;
7 forming a first insulating layer over each of the first charge control electrodes;
8 depositing a second conductive material in each trench and then etching the
9 second deposited conductive material to form a second charge control electrode in each
10 trench over the first insulating layer.

1 13. The method of claim 11 further comprising:
2 forming a plurality of trenches extending into the semiconductor region, the
3 plurality of charge control electrodes being formed in the plurality of trenches; and
4 forming a plurality of shallow regions in a top surface region of the
5 semiconductor region between adjacent pairs of the plurality of trenches such that the metal

6 layer is in direct contact with the shallow regions, the shallow layer having the same
7 conductivity type as but a lower doping concentration than that of the semiconductor region.

1 14. The method of claim 13 further comprising forming the plurality of
2 charge control electrodes in the plurality of trenches such that the plurality of charge control
3 electrodes are insulated from one another and from the semiconductor region.

1 15. The method of claim 13 wherein the semiconductor region and the
2 shallow layer are n-type.

1 16. The method of claim 11 wherein the method further comprises forming
2 a plurality of biasing elements on or in the semiconductor region, wherein the biasing
3 elements are adapted to bias the at least two charge control electrodes at different voltages.

1 17. The method of claim 11 wherein the first and second charge control
2 electrodes comprise polysilicon.

1 18. A Schottky diode comprising:
2 a metal layer and a semiconductor region forming a Schottky barrier
3 therebetween; and
4 a first trench extending in the semiconductor region, the first trench having at
5 least one diode therein.

1 19. The Schottky diode of claim 18 wherein the at least one diode is
2 reverse biased during Schottky diode operation.

1 20. The Schottky diode of claim 18 further comprising an insulating layer
2 which lines the sidewalls of the first trench but is discontinuous along the bottom of the first
3 trench.

1 21. The Schottky diode of claim 18 wherein the first trench further
2 includes an insulating layer configured to insulate the at least one diode from the
3 semiconductor region along the sidewalls of the first trench.

1 22. The Schottky diode of claim 18 wherein the semiconductor region is
2 an epitaxial layer formed over and in contact with a substrate.

1 23. The Schottky diode of claim 22 wherein the first trench extends into
2 the epitaxial layer and terminates at an interface between the semiconductor region and the
3 epitaxial layer.

1 24. The Schottky diode of claim 22 wherein the first trench extends into
2 and terminates within the epitaxial layer.

1 25. The Schottky diode of claim 18 wherein the at least one diode is
2 arranged in the first trench so that when the Schottky diode is biased in a blocking state an
3 electric field induced in the at least one diode influences an electric field in the
4 semiconductor region to thereby increase the blocking voltage of the Schottky diode.

1 26. The Schottky diode of claim 18 wherein the at least one diode is
2 arranged in the first trench so that when the Schottky diode is biased in a blocking state an
3 electric field induced in the at least one diode results in a substantially uniform charge
4 distribution in the semiconductor region.

1 27. The Schottky diode of claim 18 wherein the at least one diode includes
2 n-type and p-type regions alternately stacked on top of one another in the trench.

1 28. The Schottky diode of claim 18 wherein the at least one diode
2 comprises a p-type silicon region in contact with an n-type silicon region.

1 29. The Schottky diode of claim 18 wherein the at least one diode
2 comprises a p-doped polycrystalline silicon material in contact with an n-doped
3 polycrystalline silicon material.

1 30. The Schottky diode of claim 18 further comprising a shallow region on
2 each side of the first trench in a top surface region of the semiconductor region such that the
3 metal layer is in direct contact with the shallow region to form a Schottky barrier
4 therebetween, the shallow region having the same conductivity type as but a lower doping
5 concentration than the semiconductor region.

1 31. The Schottky diode of claim 30 wherein the semiconductor region and
2 the shallow region are n-type.

1 32. The Schottky diode of claim 18 further comprising an anode electrode
2 coupled to the metal layer and a cathode electrode coupled to the semiconductor region, the
3 first trench extending between the anode and cathode electrodes.

1 33. A Schottky diode comprising:
2 a metal layer;
3 a semiconductor region in contact with the metal layer to form a Schottky
4 barrier junction therebetween;
5 a plurality of laterally spaced trenches each extending through at least a
6 portion of the semiconductor region; and
7 a plurality of diodes in each of the plurality of trenches, the plurality of diodes
8 in each trench being insulated from the semiconductor region along the trench sidewalls,
9 wherein the plurality of diodes in each trench are reverse-biased during
10 operation.

1 34. The Schottky diode of claim 33 wherein the plurality of diodes are
2 positioned in each of the plurality of trenches such that an electric field induced in one or
3 more of the plurality of diodes influences an electric field in the semiconductor region such
4 that a blocking voltage of the Schottky diode is increased.

1 35. The Schottky diode of claim 33 wherein each of the plurality of
2 trenches further includes an insulating layer which lines the trench sidewalls but is
3 discontinuous along the bottom of the trench.

1 36. The Schottky diode of claim 33 further comprising at least two
2 terminals located along opposite surfaces of the Schottky diode, the at least two terminals
3 being configured to bias the Schottky diode during operation,
4 wherein the plurality of trenches extends vertically between the two terminals,
5 and the plurality of diodes in each trench includes p-type and n-type regions alternately
6 stacked on top of each other in each trench.

1 37. The Schottky diode of claim 33 further comprising a plurality of
2 shallow regions each formed in a top surface region of the semiconductor region between
3 adjacent pairs of the plurality of trenches such that the metal layer is in direct contact with the

4 shallow region, the shallow region having the same conductivity type as but a lower doping
5 concentration than the semiconductor region.

1 38. A method of forming a Schottky diode, comprising:
2 forming a first trench extending in a semiconductor region; and
3 forming at least one diode in the first trench; and
4 overlaying the semiconductor region with a metal layer to thereby form a
5 Schottky barrier therebetween.

1 39. The method of claim 38 further comprising:
2 forming an insulating layer which extends along sidewalls of the first trench
3 but is discontinuous along the bottom of the first trench.

1 40. The method of claim 38 further comprising:
2 forming an insulating layer configured to insulate the at least one diode from
3 the semiconductor region along the sidewalls of the first trench.

1 41. The method of claim 38 wherein the semiconductor region is an
2 epitaxial layer, the method further comprising:
3 forming the epitaxial layer over and in contact with a substrate, the epitaxial
4 layer being of the same conductivity type as the substrate.

1 42. The method of claim 38 wherein the at least one diode is arranged in
2 the first trench so that when the Schottky diode is biased in a blocking state an electric field
3 induced in the at least one diode influences an electric field in the semiconductor region to
4 thereby increase the blocking voltage of the Schottky diode.

1 43. The Schottky diode of claim 38 wherein the at least one diode is
2 arranged in the first trench so that when the Schottky diode is biased in a blocking state an
3 electric field induced in the at least one diode results in a uniform charge distribution in the
4 semiconductor region.

1 44. The method of claim 38 wherein the step of forming at least one diode
2 comprises forming n-type and p-type regions alternately stacked on top of one another in the
3 first trench.

1 45. The method of claim 38 further comprising:
2 forming a plurality of shallow regions in a top surface region of the
3 semiconductor region between adjacent pairs of the plurality of trenches such that the metal
4 layer is in direct contact with the shallow regions to form a Schottky barrier therebetween, the
5 shallow layer having the same conductivity type as but a lower doping concentration than that
6 of the semiconductor region.

1 46. The method of claim 45 wherein the semiconductor region and the
2 shallow layer are n-type.

1 47. The method of claim 38 wherein the at least one diode is from one of
2 doped silicon material and doped polysilicon material.

1 48. A method of forming a Schottky diode, comprising:
2 forming a plurality of laterally spaced trenches in a semiconductor region,
3 each trench extending through at least a portion of the semiconductor region;
4 forming a plurality of diodes in each of the plurality of trenches; and
5 overlaying the semiconductor region with a metal layer so as to form a
6 Schottky barrier therebetween.

1 49. The method of claim 48 wherein the plurality of diodes are formed in
2 each of the plurality of trenches such that an electric field induced in one or more of the
3 plurality of diodes influences an electric field in the semiconductor region such that a
4 blocking voltage of the Schottky diode is increased.

1 50. The method of claim 48 further comprising:
2 forming an insulating layer in each of the plurality of trenches, the insulating
3 layer extending along the trench sidewalls but being discontinuous along the bottom of the
4 trench.

1 51. The method of claim 48 further comprising:
2 forming at least two terminals located along opposite surfaces of the Schottky
3 diode, the plurality of trenches extending vertically between the two terminals,
4 wherein the step of forming a plurality of diodes comprises forming p-type
5 and n-type regions alternately stacked on top of each other in each trench.

1 52. The method of claim 48 further comprising:
2 before forming the plurality of trenches, forming a shallow layer along an
3 upper surface of the semiconductor region, the shallow layer having the same conductivity
4 type as but a lower doping concentration than that of the semiconductor region, the plurality
5 of trenches extending through the shallow layer and into the semiconductor region such that
6 the shallow layer is broken up into a plurality of shallow regions between adjacent trenches,
7 wherein the metal layer is in direct contact with the plurality of shallow regions to form a
8 Schottky barrier therebetween.